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AN AREA-TIME INTEGRAL ANALYSIS OF NEXRAD DATA

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1. INTRODUCTION

The existence of a strong correlation (typically r>0.97) between radar echo area-time integrals (ATI's) and rain volumes produced by the corresponding storms is well established (Doneaud *et al.*, 1984; Lopez *et al.*, 1989; Johnson *et al.*, 1994). However, there appear to be regional differences in the rain volume - ATI relationships and possible dependency on the radar beamwidth and wavelength (Johnson and Smith, 1990), which should be investigated. Values of the regression coefficients are affected by the chosen reflectivity threshold as well, and further study of this behavior is warranted. A preliminary study of rain volume - ATI relationships from analysis of data collected by the Atlanta WSR-88D has explored these matters.

Radar reflectivity data have long been used to generate rain rate values that are integrated over temporal and spatial domains to produce estimates of rainfall amounts. The rain volume can be estimated for either an area with fixed boundaries (Eulerian frame of reference) or for an individual storm, employing a Lagrangian framework. Physical mechanisms can alter the reflectivity values from those due to just precipitation particles alone; among them are ground clutter and second trip echoes. The present NEXRAD precipitation algorithm includes software corrections for these mechanisms.

The ATI calculation from radar reflectivity data uses only the area enclosed within a threshold contour. This area is multiplied by the time interval between scans, and the area-time product is integrated over the period of interest to yield the ATI value. Knowledge of the interior reflectivity structure, Doppler velocity field, spectral widths, or polarizations does not influence this simple procedure. The correlation between the ATI and corresponding rain amounts, whether derived from radar data or (where available) from gage data, is consistently strong. Application of the procedure to either a moving storm or a fixed area on the ground works equally well.

2. ATI ANALYSIS OF NEXRAD DATA

The ATI analysis was applied to NEXRAD (WSR-88D; S-band, 1 deg beamwidth) data collected at Atlanta, Georgia during May and June 1995. The primary intent of this study was to correlate GOES IR satellite ATI calculations with rainfall estimates generated by the radar. The study approach requires that the reference remain Lagrangian, affixed to the storm motion. The first portion of the study identified individual storms that played out their lifetime within the radar's surveillance area and produced radar ATI's along with the rainfall estimate for each. Low-elevation scans were used throughout and the traditional threshold reflectivity of 25 dBZ (R~1 mm h^{-1}) was applied to determine the ATI's. The scatter plot of the ATI's compared to the radar-estimated rain volumes, presented in Fig. 1, resulted in a correlation of 0.98 for 204 storms. The rain from these storms covered areas over their lifetimes ranging from very small (51 km^2) to large (44530 km^2) and averaged 4000 km^2. The typical storm was initiated between 1300 and 2000 local time, during maximum heating, and lasted about an hour and a half. A total of 13800 k tonne of rain was produced by this average storm; rain amounts ranged from 2-750,000 k tonne.

The log-log regression resulted in the power law:

$$\text{RERV} = 3.39\,(\text{ATI})^{1.11}$$

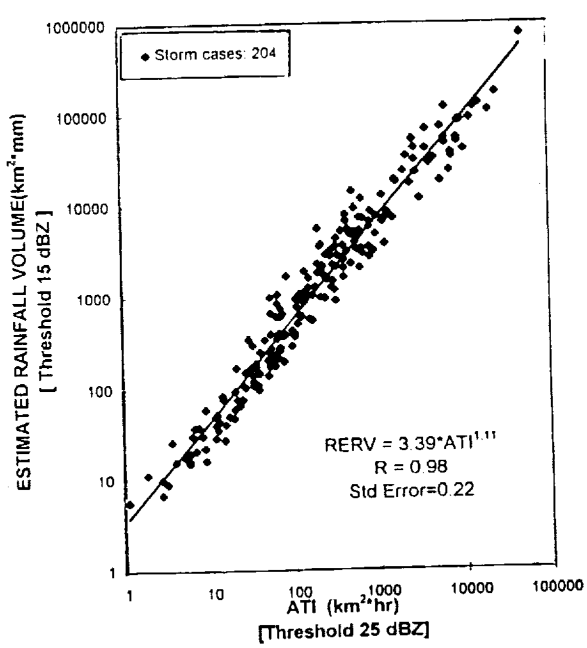

Figure 1. Scatter plot and regression line of RERV-ATI relationship under ATI threshold of 25 dBZ. RERV-ATI relationship is **RERV=3.39(ATI)$^{1.11}$**.

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to estimate rain volume (RERV) where 1.11 is the slope (b) and 3.39 is the antilog of the intercept (K). These results were compared to similar values determined for data collected by other radars or representing other geographic regions. Data recorded by the WSR-57 radar (S-band, 2 deg beamwidth) located at Nashville, Tennessee in a similar study produced K=5.71 and b=1.06 for 287 cases (Johnson *et al.* 1994). An earlier study of data recorded by the Skywater radar (C-band, 1 deg beamwidth) at Miles City, Montana resulted in K=2.12 and b=1.09 (Johnson and Hjelmfelt, 1990). A neighboring project in North Dakota using two Enterprise radars (C-band, 2 deg beamwidth) resulted in K=3.07 and b=1.08 (Doneaud *et al.* 1984). Thus, the exponent b varies little from radar to radar and from region to region. The coefficient K has units of mm h^{-1} and the physical connotation of an average rain rate; in this comparison it varies by more than a factor 2. Average rain rate in the northern plains might be expected to differ from that of the southeastern states. The difference in the K values for neighboring radars may suggest an influence of beamwidth on the analysis. In each case the data from the 2 deg beam yield a coefficient half again as large as that from the 1 deg radar.

The percentage of storm rain volume not actually included within the 25 dBZ contour used in the determination of the ATI's was approximately 18%, but varied from 1% to 87% over the individual storms. This rain must be light, with rain rates < 1 mm h^{-1} by design, and most likely had a stratiform character with little contribution at gage level. Further discrimination of convective rainfall from stratiform appears possible by manipulation of the ATI threshold to lower the standard error in the regression of RERV on ATI. The "optimized threshold" was found to be 33 dBZ (R=4 mm h^{-1}), which produced a correlation of 0.99 for 196 cases and minimized the standard error to 0.18 (from 0.22 for the 25 dBZ threshold). Approximately 34% of the total rain is not included within the 33 dBZ threshold, and is possibly ascribed to stratiform rain as the source. The 33 dBZ threshold scatter plot and regression line are presented in Fig. 2, where K=19.91 and b=1.00. An exponent of 1 implies that with the 33 dBZ threshold, the convective rain (so defined) is directly correlated with total rainfall, and that individual storm ATIs and rain volumes are additive.

3. Conclusions

The ATI analysis applied to NEXRAD data provides rain volume-ATI correlations as strong as those noted previously. Comparison among different radars suggests a beamwidth effect on the regression coefficient Moreover, it appears that manipulation of the ATI threshold may be able to separate the stratiform fraction of the rainfall from the convective part.

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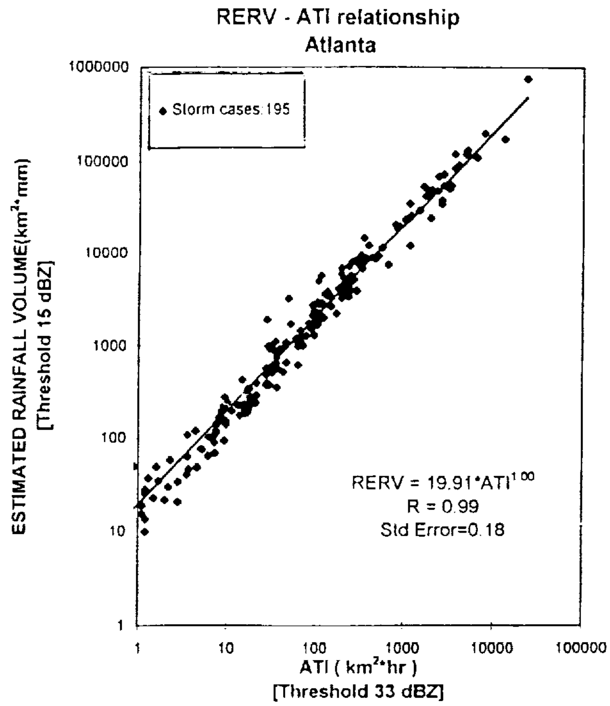

Figure 2. Scatter plot and regression line of RERV-ATI relationship under ATI threshold of 33 dBZ. RERV-ATI relationship is **RERV=19.91(ATI)$^{1.00}$**.

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